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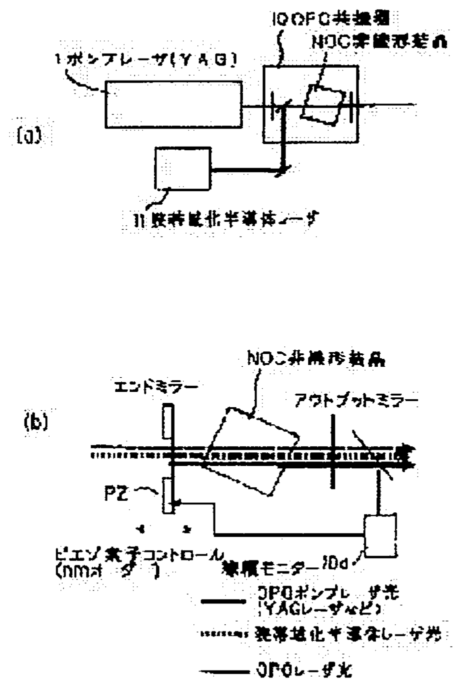
(54) OPTICAL PARAMETRIC OSCILLATION LASER DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To remove the complicatedness of an optical system and to relax restrictions on its use environment by making the output light of a narrow-band semiconductor laser incident on an optical parametric resonator(OPO resonator) in addition to a pump wave.
SOLUTION: The laser light from a pump laser 1 is inputted to the OPO resonator 10, which performs laser oscillation by utilizing the parametric effect of nonlinear crystal NOC to obtain signal light S and idler light I. In addition to the OPO resonator 10, the narrow-band semiconductor laser 11 is provided which has, for example, relaxed usable temperature variation of ±5° C and is superior in stability. The narrow-band semiconductor laser 11 oscillates the same wavelength as the oscillation wavelength λ2 or λ3 of the signal light S or idler light I by the OPO resonator 10 and the laser light is made incident on the OPO resonator 10 to equalize the oscillation wavelength λ2 or λ3 in the resonator 10 to the wavelength of the narrow-band semiconductor laser 11, thereby narrowing down the oscillation wavelength of the OPO resonator 10.



LEGAL STATUS

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CLAIMS

[Claim(s)]
[Claim 1] Optical-parametric-oscillation laser equipment which carried out incidence of the output light of narrow-band-ized semiconductor laser to the optical parametric resonator in addition to the pump wave.
[Claim 2] Optical-parametric-oscillation laser equipment according to claim 1 into which the cavity length of an optical parametric resonator is changed into according to the output light of the above-mentioned narrow-band-ized semiconductor laser, and the include angle of nonlinear crystal was changed.
[Claim 3] Optical-parametric-oscillation laser equipment according to claim 1 which exchanged the semi-conductor of an ingredient presentation with which oscillation wavelength regions differ in the above-mentioned narrow-band-ized semiconductor laser.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the optical-parametric-oscillation laser equipment which made wavelength adjustable narrowly oscillation line width of face of laser.
[0002]
[Description of the Prior Art] What it is in a laser beam and that oscillation line width of face is narrowed for (it narrow-band-izes) will improve the resolution of equipment, and, for this reason, the appearance of a laser beam with narrow line breadth is demanded in the field of the field of spectroscopy using a laser beam, interference of light, and photolysis ability measurement etc. For example, in the field of spectroscopy, the energy structure of an atom or a molecule can be correctly grasped by narrowing oscillation line width of face of laser.
[0003] There is a technique of on the other hand changing the wavelength of a laser beam using the optical parametric oscillation using nonlinear crystal. Optical parametric oscillation (OPO:Optical Parametric Oscillation is called below) As shown in drawing 7 , it is the single wavelength lambda 1. If incidence of the laser beam (pump wave P) is carried out to the nonlinear crystal NOC, such as BBO (beta-BaB 2 O4 : beta barium borate) the light of two wavelength (lambda 2 and lambda 3) occurs in the form where energy is saved -- it is -- lambda 2 -- < -- lambda 3 ** -- the time of carrying out -- wavelength lambda 2 The signal light S and wavelength lambda 3 It is called the idler light I. By constituting a laser cavity so that this signal light S and the idler light I may be amplified, it is wavelength lambda 1. Pump wave P to the wavelength lambda 2, and lambda 3 It becomes possible to generate Light S and I. wavelength lambda 1, lambda 2, and lambda 3 **** -- the following relational expression exists. [in this case,]
1/lambda1 =1/lambda2+1/lambda 3 -- lambda 2 which satisfies this formula, and lambda 3 It is determined by the phase matching process and is specifically decided by the include angle of the nonlinear crystal NOC to incidence laser beam P.
[0004] It is in such OPO laser equipment, and there is a thing as shown in drawing 8 about the narrow-band-ized OPO laser equipment which narrows Rhine line breadth. It is drawing in which drawing 8 (a) shows the simple block diagram of equipment, and drawing 8 (b) shows the optical path and structure of a narrow-band-ized resonator among drawing 8 (a). Incidence of the laser beam of pump LD 1 is carried out to the narrow-band-ized resonator 2 which is OPO laser equipment, a laser beam with the narrow Rhine width of face is oscillated so that it may become clear from this drawing, that laser beam is amplified with the amplifier resonator 3 which is another OPO laser equipment, and only light with the narrow line breadth which has arranged Grating dg at the end of a resonator and was chosen as it by include-angle adjustment of Grating dg is amplified in the narrow-band-ized resonator 2. In this case, according to change of wavelength, include-angle adjustment of the nonlinear crystal NOC of narrow-band-ized resonator 2 and amplifier resonator 3 both sides is also needed.
[0005]
[Problem(s) to be Solved by the Invention] As shown in drawing 8 , in the former, the OPO oscillator for narrow-band-izing and the OPO oscillator for magnification are combined, and it

will be necessary to carry out by synchronizing adjustment of a grating, and include-angle adjustment of two nonlinear crystal, and control and actuation of optical system become complicated. Moreover, since the narrow-band-ized per OPO resonator is used, it will be necessary to stabilize temperature per [of pump LD 1 and the whole resonator] unit but, a temperature control is difficult in a big unit, and if it says conversely, it is necessary to make an operating environment (especially temperature) limit very severe. Specifically, an usable temperature change is restricted to **2 degrees C.

[0006] This invention aims at offer of the optical-parametric-oscillation laser equipment which was made to make an operating environment loose except for the complexity of optical system in view of an above-mentioned problem.

[0007]

[Means for Solving the Problem] In order to attain the above-mentioned purpose, this invention has the following invention specification matter.

(1) It is characterized by carrying out incidence of the output light of narrow-band-ized semiconductor laser to an optical parametric resonator in addition to a pump wave.

(2) In the above (1), it is characterized by changing the cavity length of an optical parametric resonator according to the output light of the above-mentioned narrow-band-ized semiconductor laser, and changing the include angle of nonlinear crystal.

(3) In the above (1), it is characterized by exchanging the semi-conductor of an ingredient presentation with which oscillation wavelength regions differ by the above-mentioned narrow-band-ized semiconductor laser.

[0008]

[Embodiment of the Invention] Here, the gestalt of operation of this invention is explained with reference to drawing 1 - drawing 6 . The simple configuration (a) and optical-path explanation (b) of an example are shown, and the laser beam from pump LD (YAG laser etc.) 1 is inputted in the OPO resonator 10, and with this OPO resonator 10, drawing 1 makes laser oscillation perform using the parametric effectiveness of nonlinear crystal NOC, and obtains the signal light S and the idler light I.

[0009] On the other hand, it has the narrow-band-ized semiconductor laser 11 which whose usable temperature change with the another for example, OPO resonator 10 was as loose as **5 degrees C, and was excellent in stability. This narrow-band-ized semiconductor laser 11 has a resonator on the outside of semiconductor laser 11a, as shown in drawing 2 , it is installing grating 11dg in an end, and can change the wavelength of the reflected light by changing the grating include angle to incident light using the phenomenon of reflecting this single wavelength of grating 11dg in the direction of incidence. Since it can miniaturize on structure, semiconductor laser 11a carries out temperature control of the narrow-band-ized semiconductor laser 11 whole, and it can perform simply making effect hard to be influenced to change of a room temperature, and, moreover, it is made as for it to low cost.

[0010] The oscillation wavelength lambda 2 of the signal light S according to the OPO resonator 10 by the narrow-band-ized semiconductor laser 11, or the idler light I, and lambda 3 By oscillating the same wavelength and carrying out incidence (seed) of the laser beam to the OPO resonator 10 As shown in drawing 3 , it is the oscillation wavelength lambda 2 in this resonator 10, Or lambda 3 It can be made in agreement with the wavelength of the narrow-band-ized semiconductor laser 11, and oscillation wavelength of the OPO resonator 10 can be narrow-band-ized.

[0011] In addition, since the laser beam width of face of the narrow-band-ized semiconductor laser 11 is very narrow (1 or less [for example, / 0.01cm -]), in order to align the oscillation output of the OPO resonator 10 with the wavelength of this narrow-band-ized semiconductor laser 11, it is required for it to control the cavity length of the OPO resonator 10, for this reason, as shown in drawing 1 (b), cavity length is changed using a piezo-electric element PZ, and stability of the oscillation wavelength of the OPO resonator 10 and maintenance of narrow-band-izing are achieved. the applied voltage of the piezo-electric element PZ with which equipped the OPO resonator 10 with line breadth monitor 10a, and was made to correspond to the line breadth of this monitor 10a, and the mirror was specifically equipped like drawing 1 (b) -

– changing -- and a mirror location -- being very small (nm order) -- it is made to change
[0012] Moreover, the wavelength of the narrow-band-ized semiconductor laser 11 and the include angle of nonlinear crystal NOC will align, nonlinear crystal NOC also needing to be aligned and oscillator length being controlled by the piezo-electric element PZ with narrow-band-izing of the oscillation wavelength of the OPO resonator 10, to maintain narrow-band-ization of the oscillation mode of the OPO resonator 10 in practice.
[0013] Furthermore, in changing wavelength, the include angle of grating 11dg of the narrow-band-ized semiconductor laser 11 is changed, and the wavelength obtained by this and the include angle of nonlinear crystal NOC will be synchronized, it will control, and the cavity length of the OPO resonator 10 will be controlled using a piezo-electric element PZ to maintain narrow-band-ization.
[0014] Still wide range oscillation wavelength can be obtained in the narrow-band-ized semiconductor laser 11 of this invention. That is, as shown in drawing 4 , an oscillation wavelength region changes by modification of the ingredient presentation of semiconductor laser. In drawing 4 , in the range of alpha, and AlGaAs/GaAs, the range of beta and InGaAs take the range of gamma, and InGaAsP takes [InGaAlP] the wavelength region of the range of delta. Therefore, a narrow-band oscillation in a wide range wavelength region is attained by exchanging the semiconductor laser of the class from which this ingredient presentation differs. Consequently, by presentation change of a semi-conductor, the wide range oscillation of alpha, beta, gamma, and delta is attained, and, moreover, fine-tuning wavelength change is attained by include-angle accommodation of a grating etc., and narrow-band oscillation wavelength can be obtained.
[0015] Drawing 5 and drawing 6 show the example of structure of the OPO resonator 10, and the resonator structure of a ring type of being able to compare drawing 5 with the resonator structure of a linear model, comparing drawing 6 with drawing 5 , being able to miniaturize, and excelling in stability is shown.
[0016]
[Effect of the Invention] As explained above, in order for a narrow-band-ized semiconductor laser simple substance to perform a narrow-band oscillation by having made the optical parametric resonator carry out incidence of the output light of narrow-band-ized semiconductor laser to the 1st first in addition to a pump wave. Since miniaturization can be attained that it is hard to be influenced of pulse pump light unlike the case where the conventional OPO is used and narrow-band-ized semiconductor laser and an OPO resonator are controlled separately. The actuation which synchronized with a precision like a conventional method becomes unnecessary, and the stable laser oscillation is obtained, and it excels in the narrow-band-ized semiconductor laser [itself] stability, and becomes usable in a large operating environment (eased temperature conditions).
[0017] Furthermore, the unnecessary and simple adjustment of a precise synchronousr control like a conventional method is attained by changing the cavity length of an optical parametric resonator into the 2nd according to the output light of narrow-band-ized semiconductor laser, and having changed the include angle of nonlinear crystal.
[0018] Moreover, by narrow-band-ized semiconductor laser, an oscillation in a wide range wavelength region is attained the 3rd by having exchanged the semi-conductor of an ingredient presentation with which oscillation wavelength regions differ.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to the optical-parametric-oscillation laser equipment which made wavelength adjustable narrowly oscillation line width of face of laser.

[Translation done.]

DESCRIPTION OF DRAWINGS

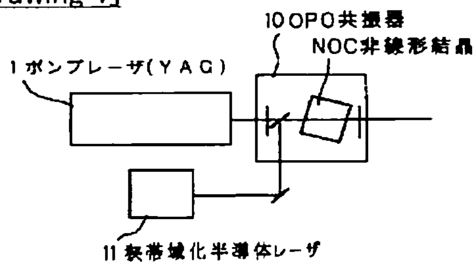
[Brief Description of the Drawings]
[Drawing 1] The configuration and resonator structural drawing of an example of operation of this invention. [of a gestalt]
[Drawing 2] The simple block diagram of narrow-band-ized semiconductor laser.
[Drawing 3] The principle Fig. showing the relation between a pump wave, signal light, and idler light.
[Drawing 4] The related Fig. of an ingredient presentation and oscillation wavelength.
[Drawing 5] Resonance structural drawing of a linear model.
[Drawing 6] Resonance structural drawing of a ring type.
[Drawing 7] The principle Fig. of a parametric oscillation.
[Drawing 8] Whole conventional example configuration and narrow-band-ized resonator structural drawing.
[Description of Notations]
1 Pump LD
10 OPO Resonator
11 Narrow-band-ized Semiconductor Laser
11a Semiconductor laser
11dg(s) Grating
NOC Nonlinear crystal
PZ Piezo-electric element
S Signal light
I Idler light

[Translation done.]

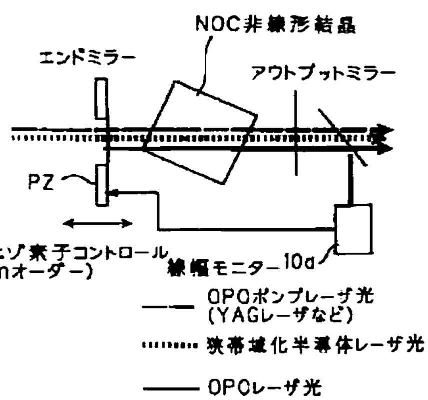
DRAWINGS

[Drawing 1]

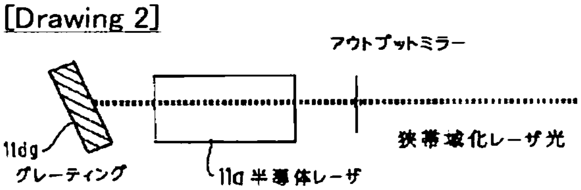
(a)



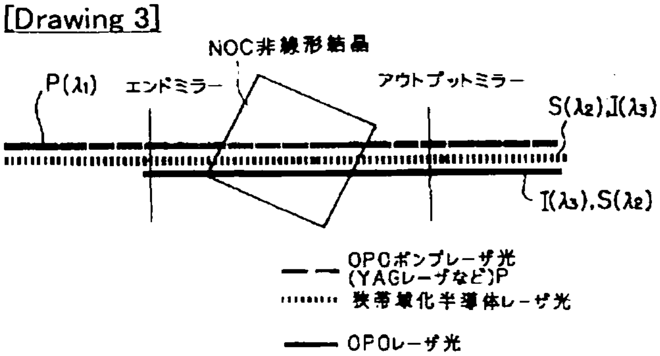
(b)



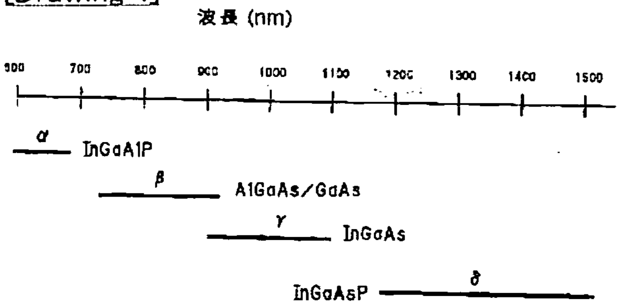
[Drawing 2]



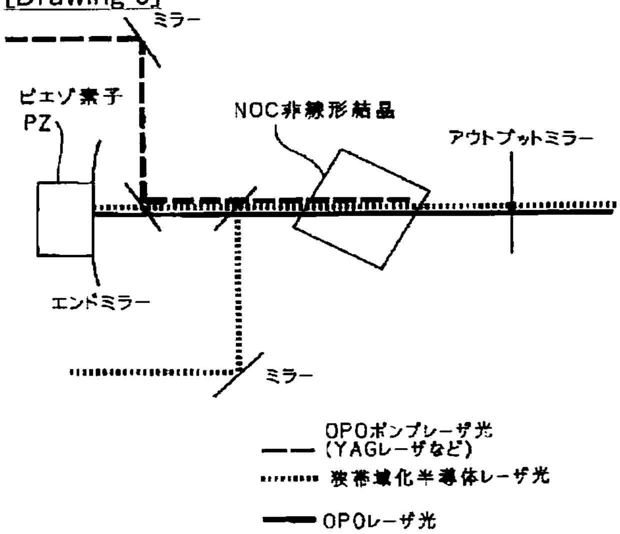
[Drawing 3]



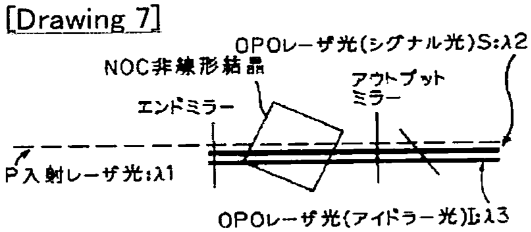
[Drawing 4]



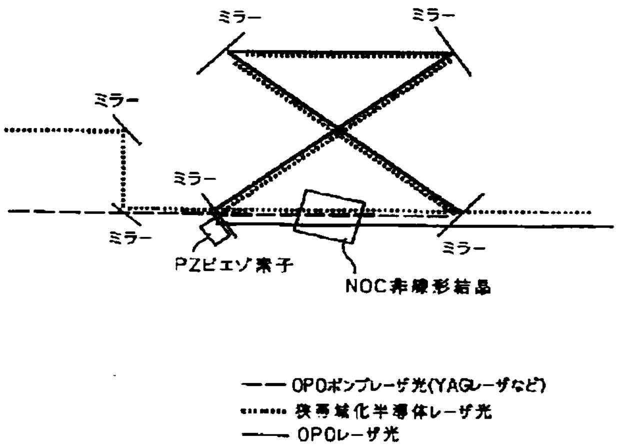
[Drawing 5]



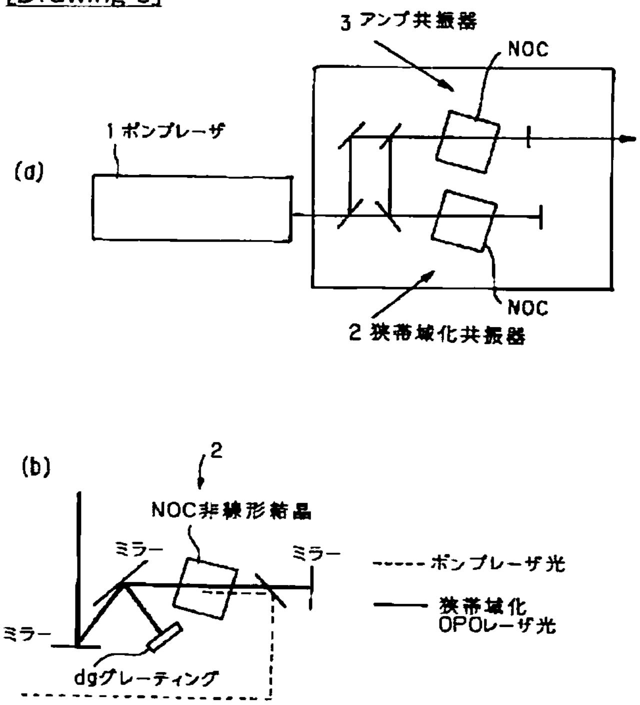
[Drawing 7]



[Drawing 6]



[Drawing 8]



狭帯域化共振器構造の一例

[Translation done.]

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審査請求　未請求　請求項の数３　ＯＬ　（全 ５ 頁）

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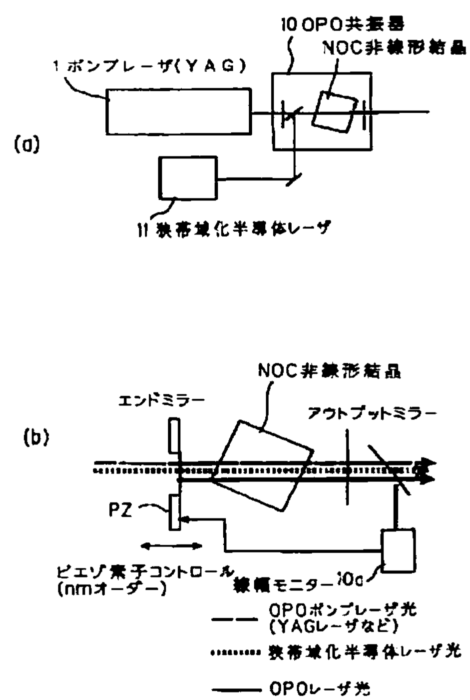
(54)【発明の名称】　光パラメトリック発振レーザ装置

(57)【要約】
【課題】　光学系が複雑とならず使用環境（温度）も緩い光パラメトリック発振レーザ装置を提供する。
【解決手段】　狭帯域化半導体レーザ１１の光をＯＰＯ共振器１０に入射（シード）してＯＰＯ発振を狭帯域化し、またＯＰＯ共振器長を制御し、更に出力波長の異なった数種の半導体レーザ１１ａを取り替えるようにしたものである。



【特許請求の範囲】

【請求項１】　狭帯域化半導体レーザの出力光をポンプ波以外に光パラメトリック共振器に入射させた光パラメトリック発振レーザ装置。

【請求項２】　上記狭帯域化半導体レーザの出力光に応じて光パラメトリック共振器の共振器長を変え非線形結晶の角度を変えるようにした請求項１記載の光パラメトリック発振レーザ装置。

【請求項３】　上記狭帯域化半導体レーザでは、発振波長域の異なる材料組成の半導体を取り替えるようにした請求項１記載の光パラメトリック発振レーザ装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、レーザの発振線幅を狭くかつ波長可変とした光パラメトリック発振レーザ装置に関する。

【０００２】

【従来の技術】レーザ光にあってその発振線幅を狭くする（狭帯域化する）ことは、装置の分解能を向上することになり、このためレーザ光を用いた分光学の分野、光の干渉、光分解能計測の分野等で線幅の狭いレーザ光の出現が要望されている。例えば、分光学の分野では、レーザの発振線幅を狭くすることにより、原子や分子のエネルギ構造を正確に把握することができることになる。

【０００３】一方、非線形結晶を利用した光パラメトリック発振を利用してレーザ光の波長を変化させる技術がある。光パラメトリック発振（以下ＯＰＯ：Optical Parametric Oscillationと称す）は、図７に示すように単一波長λ_1のレーザ光（ポンプ波Ｐ）をＢＢＯ（$\beta-BaB_2O_4$：ベータバリウムボレート）等の非線形結晶ＮＯＣに入射すると、エネルギが保存される形で二つの波長（λ_2，λ_3）の光が発生することであり、$\lambda_2 < \lambda_3$とするとき波長λ_2をシグナル光Ｓ、波長λ_3をアイドラー光Ｉと呼んでいる。このシグナル光Ｓ及びアイドラー光Ｉを増幅するようにレーザ共振器を構成することにより、波長λ_1のポンプ波Ｐから波長λ_2，λ_3の光Ｓ，Ｉを発生することが可能となる。この場合、波長λ_1，λ_2，λ_3には次の関係式が存在する。

$$1/\lambda_1 = 1/\lambda_2 + 1/\lambda_3$$

この式を充足するλ_2，λ_3は位相整合過程により決定され、具体的には入射レーザ光Ｐに対する非線形結晶ＮＯＣの角度によって決まる。

【０００４】このようなＯＰＯレーザ装置にあって、ライン線幅を狭くする狭帯域化ＯＰＯレーザ装置については、図８に示すようなものがある。図８（ａ）は装置の簡略構成図、図８（ｂ）は図８（ａ）のうち狭帯域化共振器の光路と構造を示す図である。この図から判明するようにポンプレーザ１のレーザ光をＯＰＯレーザ装置である狭帯域化共振器２に入射してライン幅の狭いレーザ光を発振させ、そのレーザ光を別のＯＰＯレーザ装置であるアンプ共振器３にて増幅するものであり、狭帯域化共振器２では共振器の一端にグレーティングｄｇを配置してグレーティングｄｇの角度調整によって選択された線幅の狭い光のみ増幅されるものである。この場合、波長の変化に応じて狭帯域化共振器２及びアンプ共振器３双方の非線形結晶ＮＯＣの角度調整も必要となる。

【０００５】

【発明が解決しようとする課題】図８に示す如く従来では狭帯域化のためのＯＰＯ発振器と増幅のためのＯＰＯ発振器とを組み合せており、グレーティングの調整及び２個の非線形結晶の角度調整を同期させて行なう必要が生じ、光学系の制御及び操作が複雑になる。また、狭帯域化につきＯＰＯ共振器を用いているため、ポンプレーザ１と共振器全体とのユニットにつき温度を安定させる必要が生じるが、大きなユニットにて温度コントロールが困難であり、逆に言えば使用環境（特に温度）制限を非常に厳しくする必要がある。具体的には使用可能な温度変化は±２℃に限られる。

【０００６】本発明は、上述の問題に鑑み、光学系の複雑さを除き使用環境を緩くするようにした光パラメトリック発振レーザ装置の提供を目的とする。

【０００７】

【課題を解決するための手段】上述の目的を達成するため本発明は、次の発明特定事項を有する。

（１）狭帯域化半導体レーザの出力光をポンプ波以外に光パラメトリック共振器に入射させたことを特徴とする。

（２）上記（１）において、上記狭帯域化半導体レーザの出力光に応じて光パラメトリック共振器の共振器長を変え非線形結晶の角度を変えるようにしたことを特徴とする。

（３）上記（１）において、上記狭帯域化半導体レーザでは、発振波長域の異なる材料組成の半導体を取り替えるようにしたことを特徴とする。

【０００８】

【発明の実施の形態】ここで、本発明の実施の形態を図１～図６を参照して説明する。図１は、一例の簡略構成（ａ）と光路説明（ｂ）とを示しており、ポンプレーザ（ＹＡＧレーザ等）１からのレーザ光がＯＰＯ共振器１０内に入力され、このＯＰＯ共振器１０では非線形結晶ＮＯＣのパラメトリック効果を利用してレーザ発振を行なわせ、シグナル光Ｓ及びアイドラー光Ｉを得る。

【０００９】他方、ＯＰＯ共振器１０とは別に例えば使用可能な温度変化が±５℃と緩くて安定性に優れた狭帯域化半導体レーザ１１が備えられる。この狭帯域化半導体レーザ１１は、図２に示すように半導体レーザ１１ａの外側に共振器を有し、一端にグレーティング１１ｄｇを設置しており、このグレーティング１１ｄｇの単一波長を入射方向に反射させるという現象を利用して入射光に対するグレーティング角度を変化させることにより反

射光の波長を変化させることができる。また、半導体レーザ１１ａは構造上小形化することができるので、狭帯域化半導体レーザ１１全体を温度調節して室温の変化に対して影響を受けにくくすることが簡単にできしかも低コストにできる。

【００１０】狭帯域化半導体レーザ１１によりＯＰＯ共振器１０によるシグナル光Ｓ又はアイドラ光Ｉの発振波長λ_2，λ_3と同一波長を発振させ、そのレーザ光をＯＰＯ共振器１０に入射（シード）することにより、図３に示すようにこの共振器１０内の発振波長λ_2又はλ_3を狭帯域化半導体レーザ１１の波長に一致させることができ、ＯＰＯ共振器１０の発振波長を狭帯域化することができる。

【００１１】なお、狭帯域化半導体レーザ１１のレーザ光線幅は非常に狭い（例えば0.０１cm^{-1}以下）ため、この狭帯域化半導体レーザ１１の波長にＯＰＯ共振器１０の発振出力を同調させるためＯＰＯ共振器１０の共振器長を制御することが必要であり、このため、図１（ｂ）に示すようにピエゾ素子ＰＺを使用して共振器長を変化させＯＰＯ共振器１０の発振波長の安定と狭帯域化の維持が図られる。具体的には、図１（ｂ）の如くＯＰＯ共振器１０に線幅モニタ１０ａを備え、このモニタ１０ａの線幅に対応させてエンドミラーに備えられたピエゾ素子ＰＺの印加電圧を変えエンドミラー位置を微少（ｎｍオーダ）に変化させるものである。

【００１２】また、ＯＰＯ共振器１０の発振波長の狭帯域化に伴って非線形結晶ＮＯＣの同調も必要であり、実際上ＯＰＯ共振器１０の発振モードの狭帯域化を維持するように発振器長がピエゾ素子ＰＺにより制御されつつ、狭帯域化半導体レーザ１１の波長と非線形結晶ＮＯＣの角度とが同調されることになる。

【００１３】更に、波長を変化するに当っては、狭帯域化半導体レーザ１１のグレーティング１１ｄｇの角度を変え、これによって得られた波長と非線形結晶ＮＯＣの角度を同期させて制御し、狭帯域化を維持するようにＯＰＯ共振器１０の共振器長をピエゾ素子ＰＺを用いて制御することになる。

【００１４】本発明の狭帯域化半導体レーザ１１では、更に広範囲な発振波長を得ることができる。すなわち、図４に示すように半導体レーザの材料組成の変更によって発振波長域が変更する。図４において、ＩｎＧａＡｌＰはαの範囲、ＡｌＧａＡｓ／ＧａＡｓはβの範囲、ＩｎＧａＡｓはγの範囲、ＩｎＧａＡｓＰはδの範囲の波長域を採る。したがって、この材料組成の異なる種類の半導体レーザを取り替えることにより、広範囲な波長域での狭帯域発振が可能となる。この結果、半導体の組成変化により、α，β，γ，δの広範囲な発振が可能となり、しかもグレーティング等の角度調節にて微調整波長変化が可能となり、そして狭帯域発振波長を得ることができる。

【００１５】図５，図６は、ＯＰＯ共振器１０の構造例を示しており、図５は直線型の共振器構造、図６は図５に比べて小型化でき安定性に優れるリング型の共振器構造を示す。

【００１６】

【発明の効果】以上説明したように、まず第１に狭帯域化半導体レーザの出力光をポンプ波以外に光パラメトリック共振器に入射させたことにより、狭帯域化半導体レーザ単体にて狭帯域発振を行なうため、従来のＯＰＯを用いた場合とは異なりパルスポンプ光の影響を受けにくくコンパクト化が図れ、また狭帯域化半導体レーザとＯＰＯ共振器とは別々に制御されるため、従来法のような精密に同期した作動が不要となり、安定したレーザ発振が得られ、また、狭帯域化半導体レーザ自体安定性に優れ、広い使用環境（緩和した温度条件）にて使用可能となる。

【００１７】更に、第２に狭帯域化半導体レーザの出力光に応じて光パラメトリック共振器の共振器長を変え非線形結晶の角度を変えるようにしたことにより、従来法のような精密な同期制御は必要なくて、簡易な調整が可能となる。

【００１８】また、第３に狭帯域化半導体レーザでは、発振波長域の異なる材料組成の半導体を取り替えるようにしたことにより、広範囲の波長域での発振が可能となる。

【図面の簡単な説明】

【図１】本発明の実施の形態の一例の構成と共振器構造図。

【図２】狭帯域化半導体レーザの簡略構成図。

【図３】ポンプ波とシグナル光及びアイドラー光の関係を示す原理図。

【図４】材料組成と発振波長との関係図。

【図５】直線型の共振構造図。

【図６】リング型の共振構造図。

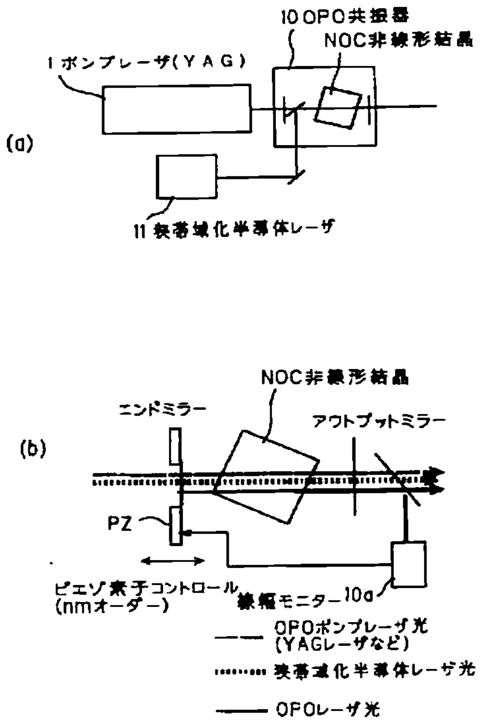
【図７】パラメトリック発振の原理図。

【図８】従来例の全体構成と狭帯域化共振器構造図。

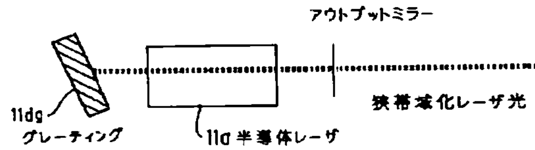
【符号の説明】

１　ポンプレーザ
１０　ＯＰＯ共振器
１１　狭帯域化半導体レーザ
１１ａ　半導体レーザ
１１ｄｇ　グレーティング
ＮＯＣ　非線形結晶
ＰＺ　ピエゾ素子
Ｓ　シグナル光
Ｉ　アイドラー光

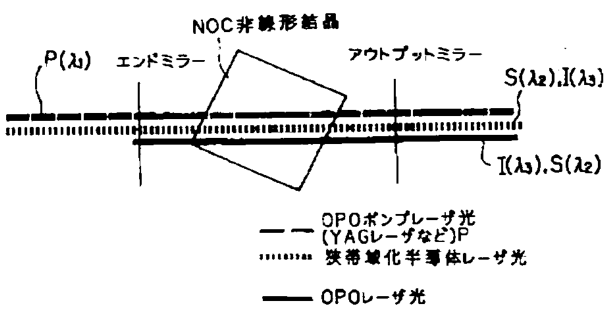
【図1】



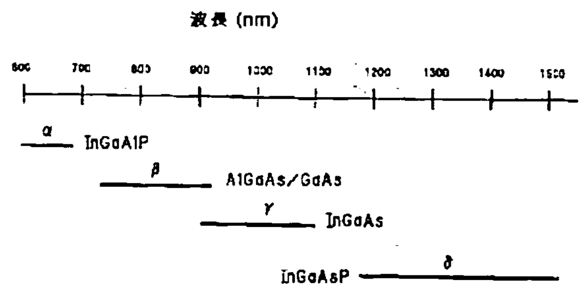
【図2】



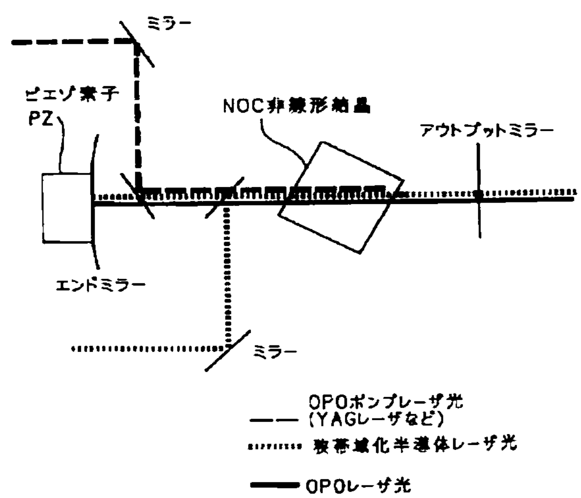
【図3】



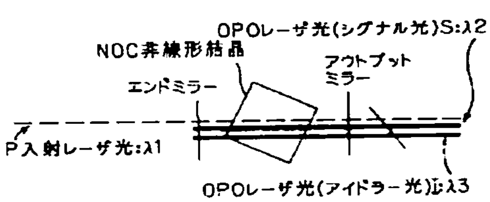
【図4】



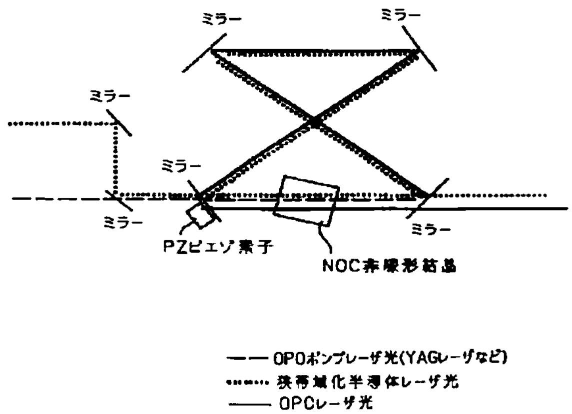
【図5】



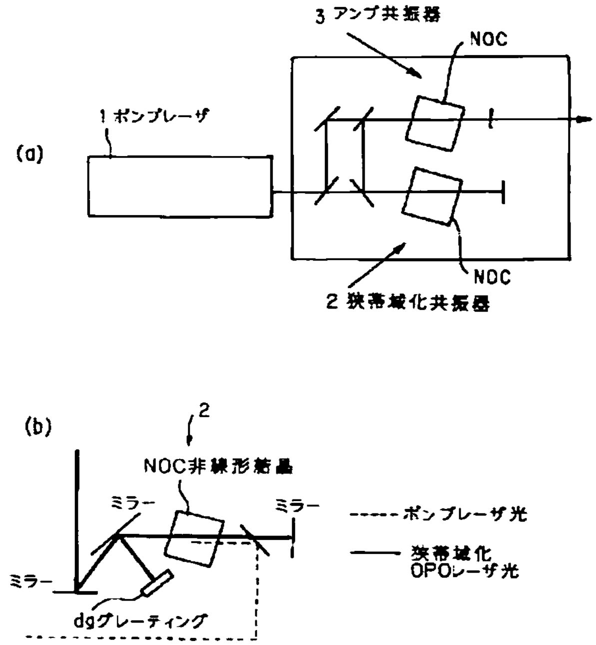
【図7】



【図6】



【図8】



狭帯域化共振器構造の一例